SUPPORT OF GULF OF MEXICO HYDRATE RESEARCH CONSORTIUM: ACTIVITIES TO SUPPORT ESTABLISHMENT OF A SEA FLOOR MONITORING STATION PROJECT

ANNUAL TECHNICAL REPORT
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Task 1: Data Management and Archiving System and Matched Field Inversion Software Development for the Sea-floor Monitoring Station

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Task 2: Experiment to generate Shear Waves in the Sea-floor and Record them with a Horizontal Line Array

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Task 3: Coupling of Continuous Geochemical and Sea-floor Acoustic Measurements

* includes seismo-acoustic characterization of sea-floor properties and processes at the hydrate monitoring station until VSP data can be collected

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ABSTRACT

The Gulf of Mexico Hydrates Research Consortium (GOM-HRC) was established in 1999 to assemble leaders in gas hydrates research. The Consortium is administered by the Center for Marine Resources and Environmental Technology, CMRET, at the University of Mississippi. The primary objective of the group is to design and emplace a remote monitoring station or sea floor observatory (MS/SFO) on the sea floor in the northern Gulf of Mexico by the year 2007, in an area where gas hydrates are known to be present at, or just below, the sea floor. This mission, although unavoidably delayed by hurricanes and other disturbances, necessitates assembling a station that will monitor physical and chemical parameters of the marine environment, including sea water and sea-floor sediments, on a more-or-less continuous basis over an extended period of time. In 2005, biological monitoring, as a means of assessing environmental health, was added to the mission of the MS/SFO.

Establishment of the Consortium has succeeded in fulfilling the critical need to coordinate activities, avoid redundancies and communicate effectively among researchers in the arena of gas hydrates research. Complementary expertise, both scientific and technical, has been assembled to promote innovative research methods and construct necessary instrumentation. The observatory has now achieved a microbial dimension in addition to the geophysical, geological, and geochemical components it had already included.

Initial components of the observatory, a probe that collects pore-fluid samples and another that records sea floor temperatures, were deployed in Mississippi Canyon 118 in May of 2005. Follow-up deployments, planned for fall 2005, had to be postponed due to the catastrophic effects of Hurricane Katrina (and later, Rita) on the Gulf Coast. Station/observatory completion, anticipated for 2007, will likely be delayed by at least one year.

The CMRET has conducted several research cruises during this reporting period: one in April, one in June, one in September. April's effort was dedicated to surveying the mound at MC118 with the Surface-Source-Deep-Receiver (SSDR) seismic surveying system. This survey was completed in June and water column and bottom samples were collected via box coring. A microbial filtering system developed by Consortium participants at the University of Georgia was also deployed, run for ~12 hours and retrieved. The September cruise, designed to deploy, test, and in some cases recover, geochemical and microbial instruments and experiments took place aboard Harbor Branch's *Seward Johnson* and employed the Johnson SeaLink manned-submersible.

The seafloor monitoring station/observatory is funded approximately equally by three federal Agencies: Minerals Management Services (MMS) of the Department of the Interior (DOI), National Energy Technology Laboratory (NETL) of the Department of Energy (DOE), and the National Institute for Undersea Science and Technology

(NIUST), an agency of the National Oceanographic and Atmospheric Administration (NOAA).

Subcontractors with FY03 funding fulfilled their technical reporting requirements in a previously submitted report (41628R10). Only unresolved matching funds issues remain and will be addressed in the report of the University of Mississippi's Office of Research and Sponsored Programs. In addition, Barrodale Computing Services Ltd. (BCS) completed their work; their final report is the bulk of the semiannual report that precedes this one, 41628R14.

Noteworthy accomplishments of Consortium researchers during this six month cycle funded with DOE's contributions to this multiagency effort include:

- Data Management and Processing Software for the Sea-floor Monitoring Station (Barrodale Computing Services Ltd. (BCS)): Completed. See 41628R14.

- Progress on the Applications of Vertical Seismic Profiling (VSP) Technology for Evaluation of Deep-Water Gas Hydrate Systems at the University of Texas Bureau of Economic Geology's Exploration Geophysics Laboratory, EGL:
    - The Bureau research team worked with deep-water 4C OBC data applying newly developed techniques to data from the Beaufort Sea.
    - The Bureau has developed software that produces P-wave impedance profiles that extend across hydrate stability zones.

- Progress on the Coupling of Continuous Geochemical and Sea-floor Acoustic Measurements:
    - 10 box cores were collected at MC118 and analyzed for light hydrocarbon gases, stable isotopes and dissolved ions. Objectives in this portion of the project are to relate the geochemistry to the geophysics to aid in the interpretation of geophysical data.
    - These cores are isotopically lighter than the vent gas, suggesting microbial methane production in the surface sediments.
    - The dissolved methane in the porewaters is a mixture of biogenic and thermogenic sources, with more biogenic methane near the surface.
    - Three cores, 1,2,5, are depleted in sulfate within 10 cm of the sediment-seawater interface.
    - Although the average sea-water chloride concentration varies, brine was not present within the surface sediments.
    - The Pore Fluid Array (PFA) which had been installed in May, 2005 was located, upright and protruding from the sediments by about 2 meters.
    - The osmo-pumps and sampling loops were recovered by the Johnson Sea Link.
    - Replacement box and pumps were interfaced to the PFA device on a subsequent dive.
    - A second PFA osmosampler was placed at the site designated

"Rudyville".
  - Pore water equilibrators were installed at three sites.
  - Methane concentration and isotope samples were collected from 8 cores at a variety of sites stressing transects across microbial mats.

- Progress on the Microbial Activity Related to Gas Hydrate Formation and Sea-floor Instabilities:
  - Samples from a 28.5m sediment core, recovered in 2002 by the *R/V Marion Dufresne* from the Mississippi Canyon, MC798, were analyzed for propensity to form gas hydrates.
  - Smectite clays promote hydrate formation; platelets slough off the clay mass and act as nuclei for hydrate formation.
  - Anionic bioproducts may collect in the interlayers of the platelets thereby becoming involved in promoting hydrate formation.
  - More analyses are necessary to establish influences of particle size distributions in sediments near gas hydrate deposits. It is thought that the variety of bioproducts existing with depth in the sediments may mask particle size effects: some bioproducts may promote hydrates and others may coat particles and retard hydrate formation.

- Progress on the Experiment to Generate Shear Waves in the Sea-Floor and Record them with a Horizontal Line Array
  - Input/Output (I/O) has developed as a digital sensor data interface that is both proprietary and elegant. SDI has managed to establish a commitment from I/O to support the Consortium's efforts.
  - Upgrades and enhancements to the I/O equipment have been made that promise to improve the functionality of the Horizontal array systems.

- Administration of the Monitoring Station/Sea-floor Observatory project this reporting period has consisted of
  - Organizing and carrying out three cruises: an April cruise to run a surface-source/deep-receiver (SS/DR) survey of MC118, a June cruise to complete the SS/DR survey and to collect samples and test equipment built by Consortium participants, and a September cruise aboard the *R/V Seward Johnson* with the Johnson SeaLink manned-submersible to conduct visual surveys of the site of the Sea-floor observatory (SFO) to collect data and a data-logger from instruments deployed at the site in May 2005, to perform additional tests, and to deploy new or replacement instruments on the sea-floor at MC118. Reports of these cruises are incomplete at this time but a "Quick" cruise report, made by Dr. Woolsey who served as Chief Scientist on the cruise, appears as an appendix to this report.
  - Reporting to and interacting with sponsoring agencies and their officers as well as with Consortium members. Two semiannual progress reports,

41628R12 and 41628R14 were completed and submitted to DOE in May and June, 2006. Monthly reports have been made to DOE each month of the reporting period and cruise reports have been completed and published to the Mississippi Mineral Resources Institute's website, http://www.olemiss.edu/depts/mmri/ for the October, 2005, and both March, 2006 cruises.

- Wall-to-Wall, an independent television programming production company, accompanied Consortium participants on the September cruise so that they might film portions of the cruise for inclusion in a miniseries for Discovery Television. They filmed portions of the visual surveying of MC118 as well as some of the deployments and related activities. The broadcast should take place in March, 2007.

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Graphical materials used to illustrate reports can be found in the individual reports submitted by the subcontractors.

INTRODUCTION / PROJECT SUMMARY

The Gulf of Mexico-Hydrate Research Consortium (GOM-HRC) is in its seventh year of developing a sea-floor station to monitor a mound where hydrates outcrop on the sea floor. The plan for the Monitoring Station/Sea Floor Observatory (MS/SFO) is that it be a multi-sensor station that provides more-or-less continuous monitoring of the near-seabed hydrocarbon system, within the hydrate stability zone (HSZ) of the northern Gulf of Mexico (GOM). The goal of the GOM-HRC is to oversee the development and emplacement of such a facility to provide a better understanding of this complex hydrocarbon system, particularly hydrate formation and dissociation, fluid venting to the water column, and associated microbial and/or chemosynthetic communities. Models developed from these studies should provide a better understanding of gas hydrates and associated free gas as: 1) a geo-hazard to conventional deep oil and gas activities; 2) a future energy resource of considerable significance; and 3) a source of hydrocarbon gases, venting to the water column and eventually the atmosphere, with global climate implications.

Initial funding for the MS/SFO was received from the Department of Interior (DOI) Minerals Management Service (MMS) in FY1998. Funding from the Department of Energy (DOE) National Energy Technology Laboratory (NETL) began in FY2000 and from the Department of Commerce (DOC) National Oceanographic and Atmospheric Administration's National Undersea Research Program (NOAA-NURP) in 2002. Some ten industries and fifteen universities, the United States Geological Survey (USGS), the US Navy, Naval Meteorology and Oceanography Command, Naval Research Laboratory and NOAA's National Data Buoy Center are involved at various levels of participation. Funded investigations include a range of physical, chemical, and, more recently, microbiological studies.

EXECUTIVE SUMMARY

A consortium has been assembled for the purpose of consolidating both the laboratory and field efforts of leaders in gas hydrates research. The Consortium, established at and administered by the University of Mississippi's Center for Marine Resources and Environmental Technology (CMRET), has, as its primary objective, the design and emplacement of a remote monitoring station on the sea floor in the northern Gulf of Mexico by the year 2007. The primary purpose of the station is to monitor activity in an area where gas hydrates are known to be present at, or just below, the sea-floor. In order to meet this goal, the Consortium has begun assembling a station that will monitor physical and chemical parameters of the sea water, sea-floor sediments, and shallow subsea-floor sediments on a more-or-less continuous basis over an extended period of time. Central to the establishment of the Consortium is the need to coordinate activities, avoid redundancies and promote effective and efficient communication among researchers in this growing area of research. Complementary expertise, both scientific and technical, has been assembled; collaborative research and

coordinated research methods have grown out of the Consortium and design and most construction of instrumentation for the sea-floor station is essentially complete.

The MS/SFO was designed to accommodate the possibility of expanding its capabilities to include biological monitoring. A portion of FY04 funding from the MMS was directed toward this effort to support the study of chemosynthetic communities and their interactions with geologic processes. In addition, results will provide an assessment of environmental health in the area of the station. NOAA -NURP has, as a focal point, investigations of the effects of deep sea activities on world atmosphere and therefore, weather. In July of 2005, the Director of the National Institute for Undersea Science and Technology (NIUST) of NOAA-NURP made a portion of that agency's budget available *via* competitive grants to researchers with proven expertise in microbial research. A sea-floor microbial observatory is an objective of that agency and these sponsored projects sited at the MS/SFO are designed to fulfill that directive.

The centerpiece of the monitoring station, as originally conceived, is a series of vertical line arrays of sensors (VLAs), to be moored to the sea floor. Each VLA was to have extended approximately 200 meters from the sea-floor. Sensors in the VLAs include hydrophones to record water-borne acoustic energy (and measure sound speed in the lower water column), thermistors to measure water temperature, tilt meters to sense deviations from the vertical induced by water currents, and compasses to indicate the directions in which the deviations occur. During discussions among the members of the geophysical subgroup of the Consortium, it was discovered that the project may be better served if some vertical arrays are converted to horizontal line arrays (HLAs). The prospective horizontal water-bottom arrays, will consist of hydrophones and 3-component accelerometers and will be laid upon, and pressed into, the soft sediment of the sea-floor. They will be arranged into a cross so that they simulate two perpendicular arrays. Their deployment will be accomplished by means of a sea-floor sled designed to lay cable and deploy probes into shallow, unconsolidated sediments. This sled will also be used as a seismic source of compressional and shear waves for calibrating the subsurface seismo-acoustic array commissioned by the Joint Industries Program (JIP).

The prototype DOE-funded VLA has been completed and tested together with the associated data-logging and processing systems. An Oceanographic Line Array (OLA) is ready to be equipped with any of a variety of geochemical sensors - thermistors, fluorometers, transmissometers, mass spectrometers, conductivity and current flow meters – and deployed at the observatory site, Mississippi Canyon 118 (MC118). Processing techniques continue to be developed for vertical array data by Consortium participants who are currently funded by the MMS.

A Remotely Operated Vehicle (ROV) mateable connector system was designed and installed in the VLA Data Acquisition and Telemetry System (DATS) deployed in 2005. This improved design has been incorporated into the VLA and the OLA components of the observatory. Positioning sensors – including compass and tilt sensors – have been completed and tested. Pressure housings rated twice that of any anticipated deployment have been built and pressure tested.

In May, 2005, the Sea-Floor Probe (SFP) was used to retrieve core samples from MC118 as part of the effort to select sites appropriate for deployment of the geophysical and geochemical probes. The northwestern portion of the mound area defined on images recovered during a C&C autonomous underwater vehicle (AUV) survey April 30-May 2, 2005, was selected for probe deployments based on information from these cores. Both the pore-fluid array and the geophysical line array were deployed via SFP at MC118 in May, 2005.

Additional MS/SFO deployments, scheduled for September and October, 2005, were delayed due to the devastation of the Mississippi Gulf Coast and environs by Hurricane Katrina and, to a lesser extent, the Louisiana Gulf Coast by Hurricane Rita. The immediate cause for delay was the removal of the *Ocean Quest*, the vessel that, with its two submersibles, was to have provided the platform from which many of the bottom-founded sensors would have been deployed and cable connections made. It would also have provided the visual survey needed to make optimal choices of deployment sites for station components. In addition, damage to ship yards and various forms of infrastructure has been extensive.

In October, 2005, March, April and June, 2006, the CMRET conducted a series of cruises to MC118 aboard the *R/V Pelican*. These cruises accomplished many of the tasks that had been planned for the Ocean Quest, including the recovery of more samples from MC118 and the deployment of a microbial filter device. A complete SS/DR survey was made and a drift camera designed, deployed and used successfully to survey the sea-floor, visually. However, a submersible or ROV was still required to accomplish many of the missions for which precise placement of instruments on the sea-floor was required.

Following several “false starts”, anticipating the use of other vessels which never did become available, the CMRET eventually secured seven days of ship time aboard the *R/V Seward Johnson* with use of its manned-submersible, the Johnson SeaLink. This vessel combination was used to retrieve the osmopump packages and data-loggers deployed in 2005, to conduct visual surveys of the observatory site at MC118 and to deploy sensors and experiments. Experiments designed to assess microbial communities and activities, hydrate host materials, and composition of pore-fluids were left on the sea-floor for several months’ data collection. Cruises to recover these instruments and data-loggers have already been scheduled for 2007.

EGL scientists have developed software that implements a new theory to create higher-resolution P-SV images of near-seafloor geology from large volumes of 4-C OBC seismic data. The approach takes advantage of the fact that shear-wave velocity in near sea-floor sediments is much slower than compressional wave velocity while their frequencies are the same. The Bureau research team worked with deep-water 4C OBC data from the Beaufort Sea and, using the new software, can produce P-wave impedance profiles that extend across hydrate stability zones.

Acoustic wipe-out zones may be indicative of active methane venting from sediments containing gas hydrate. Ten additional box cores were collected at MC118 and analyzed for light hydrocarbon gases, stable isotopes and dissolved ions. Objectives in this portion of the project are to relate the geochemistry to the geophysics to aid in the interpretation of geophysical data.

Analyses of these cores have been made and reveal that these cores are isotopically lighter than the vent gas, suggesting microbial methane production in the surface sediments. The dissolved methane in the porewaters is a mixture of biogenic and thermogenic sources, with more biogenic methane near the surface. Three cores are depleted in sulfate within 10 cm of the sediment-seawater interface.   Although the average sea-water chloride concentration varies, brine was not present within the surface sediments.

The Pore Fluid Array, which had been installed in May, 2005, was located on the first dive of the September *Seward Johnson*/Johnson SeaLink cruise, upright and protruding from the sediments by about 2 meters. The osmo-pumps and sampling loops were recovered and a replacement box and pumps were interfaced to the PFA device on a subsequent dive.

A second PFA osmosampler was placed on the sea-floor near the southwestern crater at the site designated “Rudyville”. Pore water equilibrators or “peepers” were installed at three sites at MC118. In addition to samples and data collected from these instruments, methane concentration and isotope samples were collected from 8 cores that were collected using the SeaLink at a variety of sites along transects across microbial mats.

Sediments collected from Mississippi Canyon were studied for effects of parameters possibly involved in hydrate formation. The sediments vary in mineral composition as well as in grain size. They also vary in the extent and variety of microbial activities that occur in them, suggesting a diverse bioproducts. Possibly the smallest sized particles influence hydrate nucleation initiation or surface areas influence hydrate formation rates. Indigenous pore waters of these sediments might also influence the ease of hydrate formation.

Smectite clays promote hydrate formation when basic platelets slough off the clay mass. These small platelets act as nuclei for hydrate formation. Anionic bioproducts may collect in the interlayers of the platelets and become involved in the mechanism of hydrate promotion.

It remains unclear exactly how particle size/size distributions affect hydrate formation. It is thought that the variety of bioproducts existing with depth in the sediments may mask particle size effects—that is, some bioproducts may promote hydrate formation and others may coat particles and retard hydrate formation.

SDI (Specialty Devices, Inc.) visited Input/Output Corp. in Houston, Texas and met with both the land seismic and marine seismic equipment groups to resolve issues of support and interfacing of the Digiseis accelerometer sensor to the Sea-floor Observatory (SFO) data acquisition and recovery systems. There have been upgrades and enhancements to the I/O equipment that should significantly improve the horizontal array systems.

LUMCON's *R/V Pelican* was used to initiate the SS/DR survey begun in March. This April cruise resulted in the successful running of 75 profiles on a grid with north-south lines spaced 100m apart and east-west lines at 50m spacing over the mound at MC118. With the resultant data, a 3-D model of the mound at MC118 can be constructed. During the June cruise, this survey was completed. There are now 109 profiles of very high resolution seismic data being processed by CMRET's post-doctoral student from the University of Rome.

In addition to the seismic data, box cores were recovered on the June cruise. The Ultrashort base-line (USBL) navigation system was used to locate the samples collected in support of several MS/SFO projects, including the DOE-funded "Coupling of Continuous Geochemical and Sea-floor Acoustic Measurements." Samples were also collected for Consortium members researching other geochemical and microbial issues at the site.

The *Seward Johnson* and its manned submersible, the Johnson SeaLink were used for seven days in September, primarily to retrieve the data-loggers and osmopump package deployed in May and to facilitate deployment of geochemical sensors and geochemical and microbial experiments that cannot be deployed from the sea's surface. During this critical and extremely successful cruise ten dives were made to the sea-floor. Twenty participants were able to take advantage of the submersible to survey the area and to test instruments. Documents relating to this cruise are included in an Appendix at the end of this report.

Reporting to and interacting with sponsoring agencies and their officers as well as with Consortium members is a primary administrative function of CMRET.

Two technical progress reports were completed and submitted to DOE during this reporting period: 41628R12 submitted in May, 2006 and 41628R14, submitted in June, 2006. Regular monthly reports documenting progress of subcontractors as well as the Consortium in general were also submitted.

Planning and managing the September submersible cruise included interfacing with Wall-to-Wall, an independent television programming production company under contract to Discovery Television to produce the miniseries, *Surviving the Future*, They hoped to cover gas hydrates in their installment, *Energy*, and sought participation in this cruise. With much discussion and planning, it was arranged for them to charter their own vessel, LUMCON's *Acadiana,* to film portions of the visual surveying of MC118 as well as some of the deployments and related activities. The broadcast should take place in March, 2007.

EXPERIMENTAL

Experiments are described in the individual reports submitted by the subcontractors.

RESULTS AND DISCUSSION

Results and discussion of those results are described in the individual reports submitted by the subcontractors. Reports from the subcontractors follow.

CONCLUSIONS

This report covers the accomplishments of the eighth six-month period of funding of Cooperative agreement Project #DE-FC26-02NT41628, between the Department of Energy and the Center for Marine Resources and Environmental Technology, University of Mississippi. The efforts of the Hydrates Research Consortium are reviewed; deployment of station components reported and plans for retrieval of instruments and deployments of additional station components are presented. Some projects have concluded. Others are nearing completion. Ship time remains tight in the Gulf but the CMRET currently has 24 days of ship time scheduled aboard the *R/V Pelican* in 2007. Every effort has been – and will continue to be – made to maximize Consortium members' access to and benefit from the cruises being scheduled for 2007.

Project summaries of the subcontractors' efforts appear in their reports contained within this document. All FY03 subcontractors have completed their technical reporting although financial reports are not yet complete. The CMRET continues to work with the sponsored programs officials at several institutions to resolve these delays, most of which involve incorrect reporting of cost-sharing. The VLA and the SFP are complete and have been proven. The "bubble counter" is complete and was successfully deployed on the September cruise. The "SphereIR" is essentially complete though it has never been field tested. Both it and the acoustic device have depleted funds prior to completion of their sensor packages. Laboratory studies of gas hydrates have expanded to new areas and new depths and include analyses of additional samples, some collected on this reporting period's cruises, and parameters impacting hydrate formation and stability.

Software development and innovative processing techniques are complete until additional sensor details become available. The pore-fluid studies and laboratory experiments continue to break new ground in hydrates research and to provide valuable information regarding where, in what, and to what extents – vertically and laterally – hydrates may be expected to be found in the marine environment. Representatives of these two programs have acquired new data; analyses of some are contained in this report. The pore-fluid sampling probe and thermistor geophysical probe, emplaced on the sea floor in May of 2005, have been recovered in good condition with samples and data-loggers intact. The data-logger and sample-collecting box of these components contain the first data produced at the MS/SFO. Instruments tested on the September cruise and those left on the sea-floor are described in the Appendix.

REFERENCES

Relevant references appear following contributions by the individual subcontractors.

Applications of VSP Technology for Evaluation of Deep-Water Gas Hydrate Systems

Progress report for the period
April 1, 2006 – September 30, 2006

November 15, 2006

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Abstract

The Texas Bureau of Economic Geology has developed software that implements a new theory to create higher-resolution P-SV images of near-seafloor geology from large volumes of 4C OBC seismic data. Our previous software was experimental code that was structured to analyze only small data sets. In this reporting period, this approach was expanded and applied to data from the Beaufort Sea.

Introduction

Work subcontracted to the Bureau of Economic Geology (Bureau) has been expanded to allow the Exploration Geophysics Laboratory (EGL) at the Bureau to process and interpret all horizontal-array and vertical-array seismic data acquired at the seafloor observatory constructed across Block MC118. Work during this reporting period has continued to focus on developing software that will generate optimal-resolution P-SV images of data acquired with multicomponent seismic sensors positioned on the seafloor.

Executive Summary

Investigations have shown that standard P-SV imaging of data acquired using 4C seafloor sensors does not produce the resolution of near-seafloor geology that is desired for this project. EGL scientists have developed a new concept for processing deep-water 4-OBC data that yields a significant improvement in the spatial resolution of P-SV images. The fundamental concept of this new theory is to abandon the conventional approach of common-conversion-point binning and to focus on simple common-receiver gathers to construct P-SV images. An example of our first-generation P-SV data processing was illustrated in our report of May 2005. We modified that test code so that it can process large volumes of horizontal-array data. We have shown, in the previous report, that this modified software produces the same quality image as that which excited us when we processed data using our initial algorithm. During this current reporting period, the Bureau research team worked with deep-water 4C OBC data from the Beaufort Sea to develop software that produces P-wave impedance profiles that extend across hydrate stability zones.

Experimental

Experimental activity during this period continued to focus on developing and testing software that creates high-resolution P-SV images of near-seafloor geology from deep-water 4C OBC seismic data. Previous work has been extended to deep-water 4C OBC data from the Beaufort Sea. The goal was to develop software that produces P-wave impedance profiles that extend across the hydrate stability zone.

Results and Discussion

During this current reporting period, the Bureau research team worked with deep-water 4C OBC data from the Beaufort Sea to develop software that produces P-wave impedance profiles that extend across hydrate stability zones. When these impedance profiles are divided by layer estimates of V_P, we obtain layer values of bulk density, ρ. Our future research plans are to demonstrate how these seismic-based layer estimates of V_P, V_S, and ρ allow key elastic moduli (bulk modulus K, shear modulus μ, and Poisson's ratio σ) to be determined across hydrate systems. When 4C data become available at Block MC 118, we should have a robust software system ready to analyze the data.

Conclusions

Important software needed for ongoing research at the hydrate-monitoring station has been developed and tested using data similar to those expected to be acquired across Block MC 118. Test results indicate that the software that has been developed is robust and creates higher-resolution P-SV images of near-seafloor geology than that provided by commercial contractors.

References

None.

Abbreviations and Acronyms

4-C: four-component
EGL: Exploration Geophysics Laboratory
MC: Mississippi Canyon
OBC: ocean-bottom cable
P-SV: converted-shear mode (P-wave to SV-shear wave conversion)
VSP: vertical seismic profile

Coupling of Continuous Geochemical and Sea-floor Acoustic Measurements

Progress report for the period
April 1, 2006 – September 30, 2006

November 15, 2006

Jeffrey Chanton[1] and Laura Lapham[2]

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INTRODUCTION:

During this period we participated in the following Consortium events:
1. Offshore Technology Conference (OTC) meeting, technical session devoted to the seafloor observatory:
On May 2-4, Laura Lapham attended the OTC in Houston, TX. As part of the "Hydrates as an Energy Source" session, she presented the paper "Pore Fluid Array Construction and Deployment at Mississippi Canyon Site 118, Gulf of Mexico". This paper was presented as part of the Gulf of Mexico Hydrate Research Consortium group.
2. *R/V Pelican* Cruise to MC118, June 6 to 13, 2006.
3. *Seward Johnson* Cruise to MC118, September 11 to 17, 2006.

2. June 2006 *Pelican* Cruise
We collected 10 additional box cores at MC118 and analyzed them for light hydrocarbon gases, stable isotopes and dissolved ions. Our objectives in this portion of the project are to relate the geochemistry to the geophysics to aid in the interpretation of geophysical data. The positions of the new cores are shown in Figure 1, along with the lines where geophysical data were collected previously.

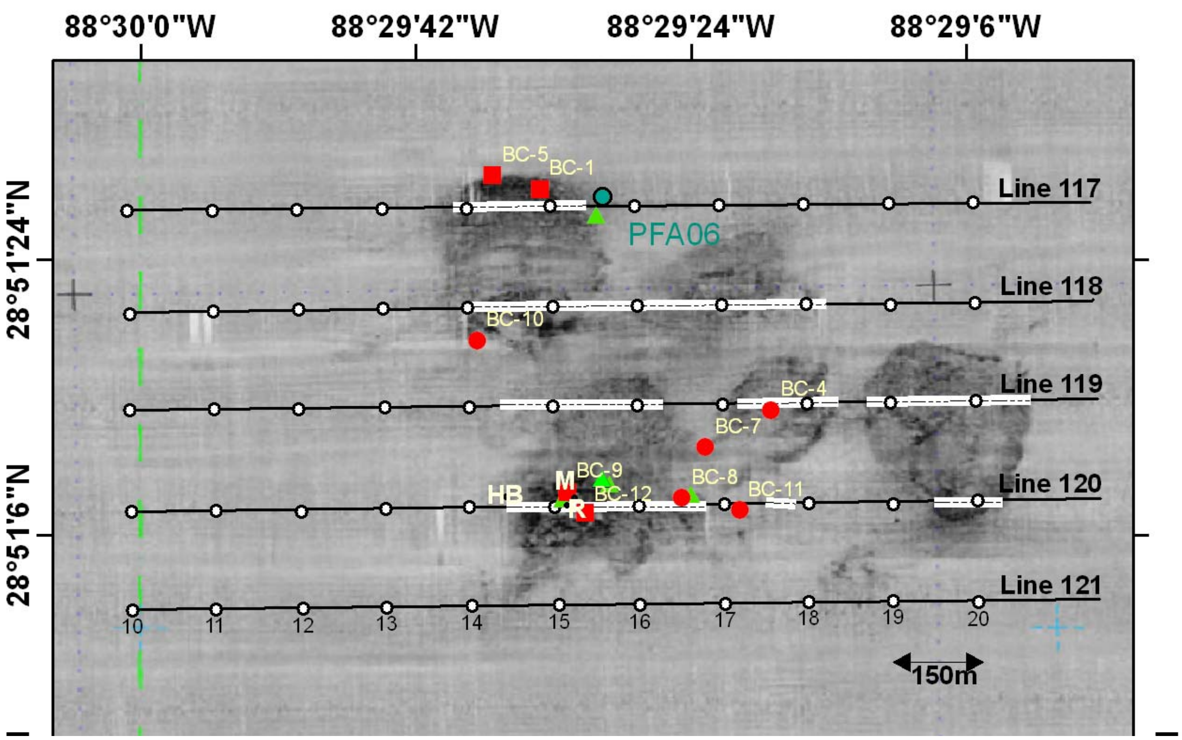


Figure 1. ***Red symbols represent the core locations from the June 2006 cruise, they are labeled with BC-core#. The core numbers correlate with core numbers given on subsequent figures. Three exposed hydrate sites are also graphed for reference. These sites were discovered in September 2006. HB= hydrate bridge, M=mandyville, and R=rudyville. Green symbols represent high microbial activity cores collected in the past.***

Results:

a. Methane and ethane concentrations

Methane concentrations in these cores ranged from background values, 1-3 micro molar to up to 10 mM in core BC-1 and 15 mM in BC-5 (Figures 2 and 3). Both these cores were bubbling when they were recovered on deck, so these concentrations represent minimum values. Oil globules were observed in cores, 5, 8, 9, 12. One of these oily cores, 9, had background methane values. It is interesting that the methane and oil don't always go together!

Ethane concentrations were also determined (data not shown). The results followed the same pattern as the methane concentrations.

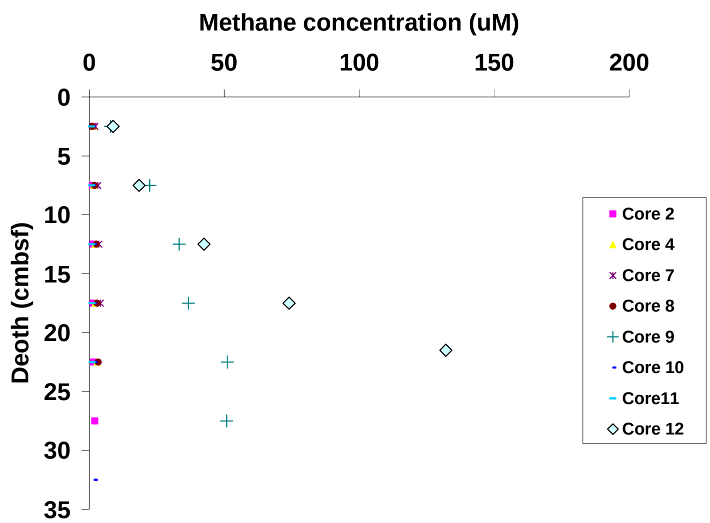


Figure 2. Low methane concentrations.

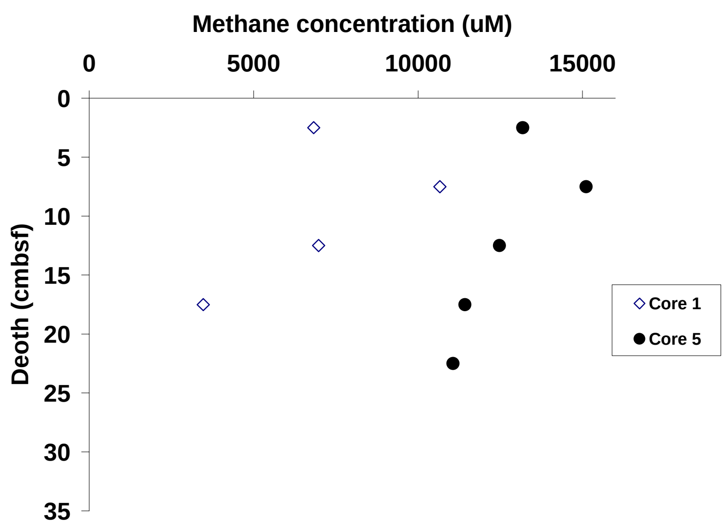
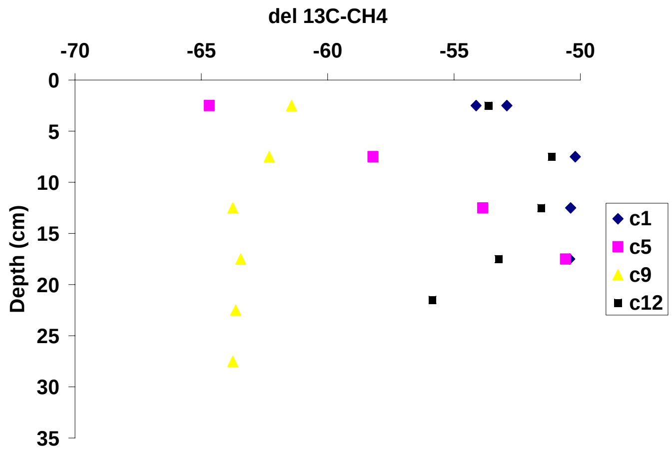


Figure 3. High methane concentrations

b. Methane isotopes

Due to limited gas within the pore-fluid samples, methane isotopes were determined on a select number of samples. The isotopic composition of vent gas at this site is -49‰ (Sassen et al., 2006). All cores analyzed are isotopically lighter than the vent gas, suggesting microbial methane production in the surface sediments.



c. Methane source

Methane found in Gulf of Mexico hydrate sites has two possible sources; biogenic or thermogenic. A biogenic source is typically pure methane, containing little to no ethane or other light hydrocarbons, and is isotopically depleted in 13C, with isotopic compositions between -60 and -90‰. In contrast, a thermogenic source is typically a mixture of methane, ethane, and other light hydrocarbons, and is isotopically enriched in 13C, with isotopic compositions between -30 and -50‰. The difference between the isotopic compositions and the gas ratios can be shown on a Bernard-style plot (Bernard et al., 1977). Since hydrates are typically a mix between these two sources, we hypothesized that the dissolved methane pool will also be a mix.

Figure 4 show that the dissolved methane is a mixture of biogenic and thermogenic sources with a depth trend evident; biogenic methane dominates the mix near the surface but grades to thermogenic at depth (data not shown).

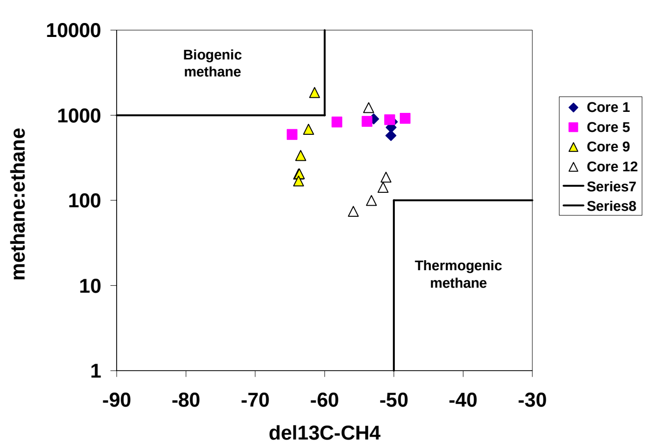
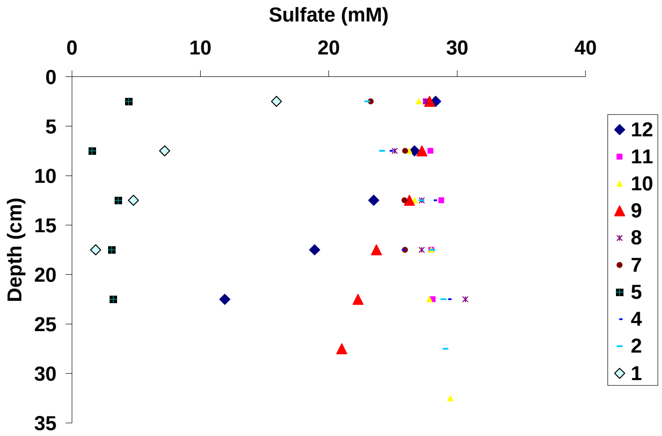


Figure 4. Bernard style plot to determine the source of the dissolved methane.

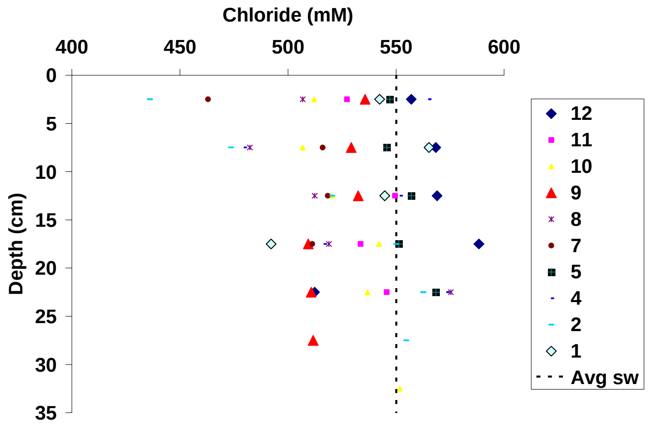
d. Sulfate concentrations

Sulfate concentrations were measured for all the cores collected. Results show that cores 1,2,5 are depleted in sulfate within 10 cm of the sediment-seawater interface.



e. Chloride concentrations

We measured pore-fluids for chloride to determine if brine was present. Results show that, although there is a bit of scatter around the average sea-water chloride concentration, brine was not present within the surface sediments.

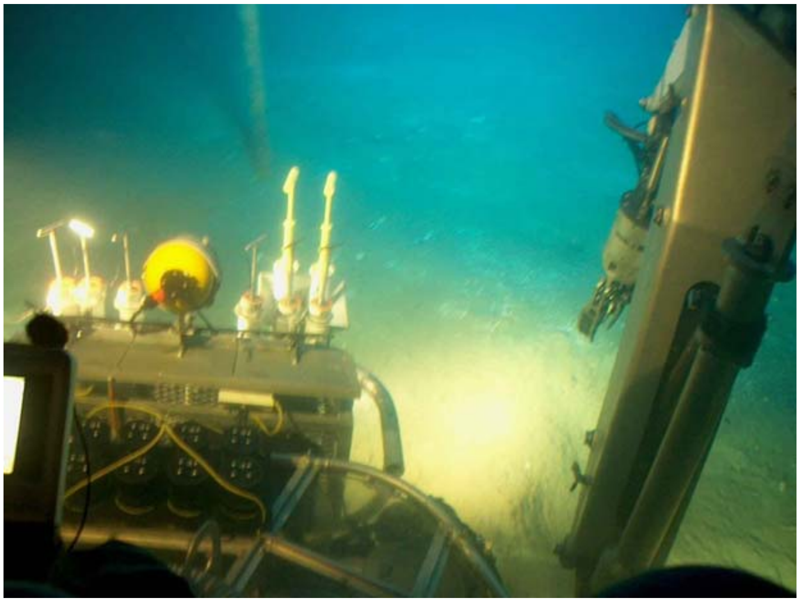


Future work: We will have DIC data soon.

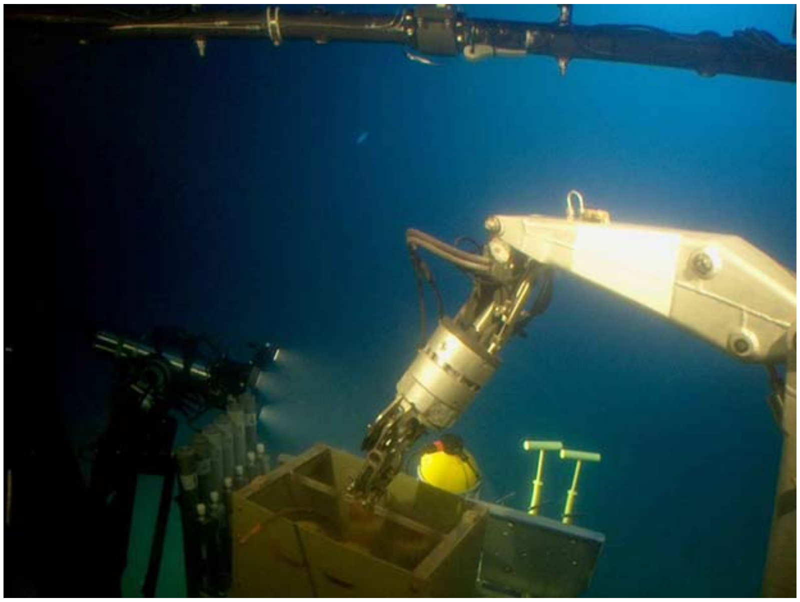
***R/V Seward Johnson* Cruise**.   The following objectives were achieved:

1. The Pore Fluid Array which had been installed in May, 2005 was located. It was upright and protruding from the sediments by about 2 meters, meaning that 8.5 meters of the probe was within the sediments (Picture 1 and 2). The osmo-pumps and sampling loops were recovered by the Johnson Sea Link on its first dive at the site (Picture 3). Depths sampled were thus overlying water 1.4 meters above the sea floor, 1.15 meters below the seafloor, 3.7 mbsf and 8.51 mbsf.
2. The replacement box and pumps were interfaced to the PFA device on a subsequent dive.
3. Depths selected for sampling were port 2 @ 20 cm above the sediment water interface, port 4, 2.23 meters below the sediment water interface, port 6, 5meters below the sediment water interface, and port 8, 8.5 meters below the sediment water interface.
4. A second PFA osmosampler was placed at the site designated "Rudyville." See Picture 4.
5. Pore water equilibrators were installed at the following sites (Table 1):
    a. Mandyville, picture 5
    b. Rudyville, 4 in a transect away from a hydrate wall picture 6
    c. Noakesville. Picture 7
6. Markers were constructed of syntactic foam and polypropylene line and deployed at each designated site (Table 1).
7. Methane concentration and isotope samples were collected from 8 cores at a variety of sites stressing transects across microbial mats.

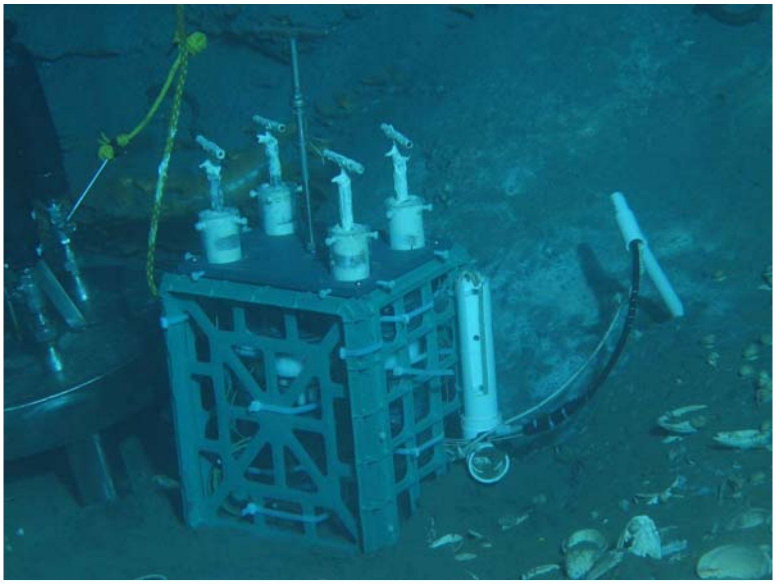
Picture 1. The PFA (pore-fluid array) which had been deployed in May, 2005 was located upright with its probe inserted into the sediments.



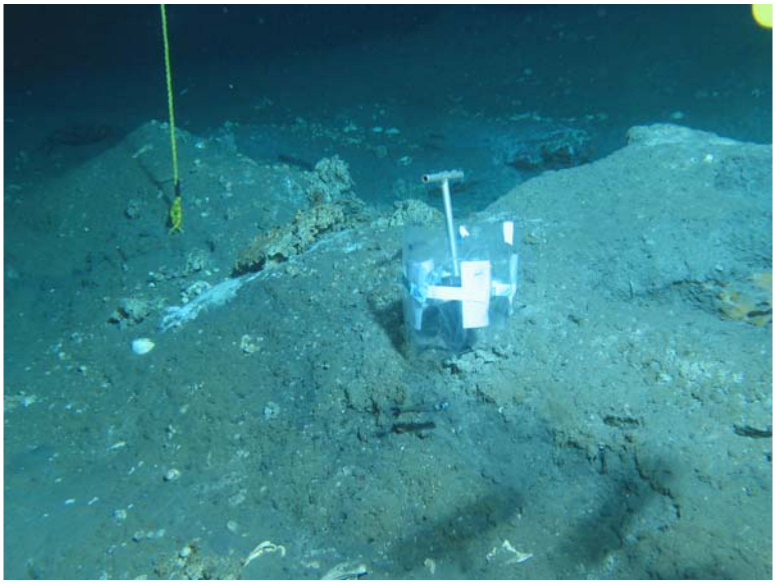
Picture 2. The PFA probe tip was about ¾ of the way inserted into the sediments.   Shown here, in the upper left is a portion that was above the sediment water interface. The good thing to notice is how straight it is! The probe was protruding from the sediments by about 2 meters, meaning that 8.5 meters of the probe was within the sediments.



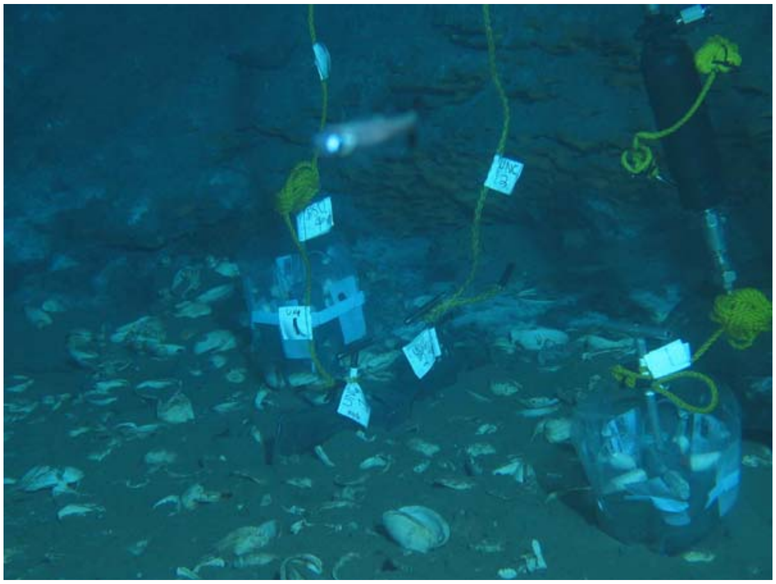
Picture 3. The PFA osmopump heads and sampler placed aboard the submarine basket.



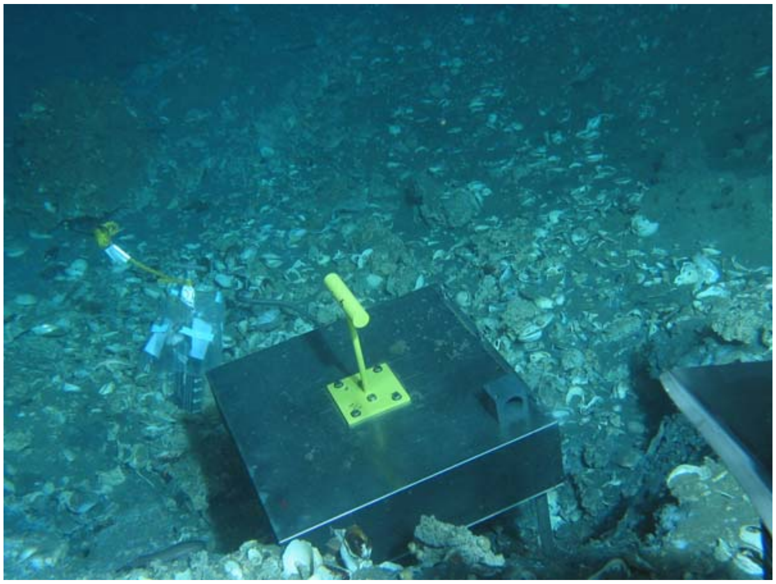
Picture 4. A smaller scale PFA/osmosampler was deployed at the base of a wall containing gas hydrate layers. Our objective is to determine the methane concentration adjacent to the gas hydrate to determine rates and controls on gas hydrate destabilization.



Picture 5. Pore-water equilibration device (peeper) to collect *in situ* methane concentrations adjacent to gas hydrate. Our objective is to determine the methane concentration adjacent to the gas hydrate to determine rates and controls on gas hydrate destabilization. This deployment was located at "Mandyville" and is directly over a gas hydrate deposit.



Picture 6. Four Pore-water equilibration devices (peepers) were placed along a transect away from a wall containing gas hydrate to determine methane concentration gradients.



Picture 7. Pore-water equilibration device (peeper) to collect *in situ* methane concentrations adjacent to gas hydrate at “Noakesville”.

References:

Bernard B. B., Brooks J. M., and Sackett W. M. (1977) *A geochemical model for characterizing hydrocarbon gas sources in marine sediments*.

Lapham L. L., Chanton J. P., Martens C. S., Higley P. D., Jannasch H. W., and Woolsey J. R. (2006) Pore Fluid Array Construction and Deployment at Mississippi Canyon Site 118, Gulf of Mexico (OTC-18170-PP). *Offshore Technology Conference*.

Sassen R., Roberts H. H., Jung W., Lutken C. B., DeFreitas D. A., Sweet S. T., and Guinasso Jr. N. L. (2006) The Mississippi Canyon 118 Gas Hydrate Site: A complex natural system. *OTC Paper #18132; Offshore Technology Conference*.

Microbial Activity Related to Gas Hydrate Formation and Seafloor Instabilities

Progress report for period April 1 – September 30, 2006

R.E. Rogers, J.L. Dearman, G. Zhang

Swalm School of Chemical Engineering, P.O. Box 9595, Mississippi State, MS 39762

ABSTRACT

Sediments in the Gulf of Mexico near gas hydrate deposits vary in clay, sand, carbonate, and other mineral contents. They also vary in the extent and variety of microbial activities that occur in them, suggesting the presence of different bioproducts. Particle sizes of the sediments vary; possibly the smallest size particles influence hydrate nucleation initiation or surface areas influence hydrate formation rates. Indigenous pore waters of these sediments might also influence the ease of hydrate formation. Such sediments were studied in the current report for effects of these parameters.

EXPERIMENTAL

Sediment Particle Sizes

Sediments from the *R/V Marian Dufresne* MD02-2570 core samples have been studied and results previously reported on hydrate induction times and hydrate formation rate trends with depths below seafloor. These cores are especially useful because they extend to about 30 meters below seafloor (mbsf), much deeper than any other available cores.

Particle size distributions were obtained for the MD02-2570 sediments for three depths: 1.5, 9.0, and 27.0 mbsf. The analyses were conducted on a Malvern MasterSizer Laser diffractor instrument. The instrument determines a volume distribution from laser diffraction patterns of a cloud of the particles, and the data are presented on the basis of an equivalent spherical diameter. The instrument can evaluate a size range from 0.02 µm to 2000 µm. From the measurements, specific surface areas, surface weighted mean diameters and volume weighted mean diameters are presented in Table I.

TABLE I. Particle sizes of MD02-2570 sediments

Sample depth, m	Specific surface area, m^2/g	Surface weighted mean dia, µm	Volume weighted mean dia, µm
1.5	3.04	1.974	7.680
9.0	2.92	2.056	9.003
27.0	2.43	2.472	7.206

RESULTS AND DISCUSSION

It is evident in Table I that mean particle diameter generally increases with depth. Comparison of volume-weighted mean diameters with surface-weighted mean diameters, shows a difference in size distributions with depth that suggests a large number of small particles in the sediments.

The smaller particles may influence induction time by providing numerous nucleation sites, but the smaller particles would also more likely be coated with bioproducts that may increase or decrease induction time depending on the bioproduct composition. Furthermore, bioproducts vary with depth. For example, near the seafloor sulfate-reducing bacteria act in consort with methane oxidizing archaea as the dominant microbial action. Below the sulfate zone, different microbial activity and consortia exist.

The larger particles may influence hydrate formation rate because they provide a larger porosity into which the hydrates can expand. The large particle size distribution observed in these analyses seemed to substantiate the trend of hydrate formation rates with depth in the MD02-2570 sediments, where rates peaked near 10- 20 m depth, as detailed in earlier reports.

Clay Nucleation Sites

Past studies in the laboratory show that smectite clays, particularly sodium montmorillonite and nontronite, substantially promote hydrate formation in sediments. This is especially true if anionic biosurfactants or anionic biopolymers are present. A series of experiments was conducted in which packings of sand and montmorillonite were saturated with emulsan and dissolved in seawater. (Emulsan is a polymeric bioproduct that is anionic. Its high molecular weight makes it more easily distinguished in scanning electron microscope photographs. Previous results have been reported that show hydrate promotion of emulsan on smectites.) The packings were placed in polypropylene containers with gas access holes drilled through the sides of the container. The samples were placed in the hydrate cell and hydrate-forming conditions established.

Hydrates form on the surface of the clay mass but migrate to fill and block the gas-access ports (gas concentration is higher there). By maintaining hydrate-forming conditions after blockage of the ports, the hydrates continue forming on the <u>outside</u> of the sample container. That is, hydrates migrate through the capillaries of the hydrates blocking the gas-access ports.

Hydrates that formed on the outside of the sample container external to the packing were collected and studied for entrained particle sizes and particle compositions. It appears from the particle size analyses and SEM photographs that basic clay particles were probably nucleating centers for the hydrate formation and that emulsan may situate in the interlayers of this swelling clay. This would mean, although clays would not have porosity or permeability for hydrates to form within their masses, that their surface platelets in conjunction with an anionic bioproduct may slough off the clay mass to help form hydrate crystals. SEM photographs of hydrate melt taken from outside the sample container suggest that the clay platelets and emulsan diffuse through the capillaries of the blocking hydrates.

CONCLUSIONS

The work indicates that smectite clays promote hydrate formation by basic platelets sloughing off the clay mass and these small platelets act as nuclei for hydrate formation. Anionic bioproducts may collect in the interlayers of the platelets and also become involved in the mechanism of hydrate promotion.

More analyses are necessary to establish hydrate influences of particle size distributions in sediments near gas hydrate deposits. It is thought that the variety of bioproducts existing with depth in the sediments may mask particle size effects—that is, some bioproducts may promote hydrates and others may coat particles and retard hydrate formation.

The DOE grants have allowed studies of these phenomena to be published in national and international journals during the current report period.

Publications of the Work

The following publications have been made during the subject report period based on the work of this grant. In the first two, acknowledgments were made of DOE grant support through the Gulf Coast Gas Hydrate Consortium at the Mississippi Mineral Resources Institute of the University of Mississippi. In the third publication, acknowledgment of the support of NOAA through N.I.U.S.T. was added to the citation.

1. Rogers, R.E., Zhang, G., Dearman, J., Woods, C., “Investigations into surfactant/gas-hydrate relationship,” *J. Petrol. Sci. & Tech.* Article accepted, proofed, and awaiting publication shortly.
2. Zhang, G., Rogers, R.E., French, W. T., and Lao, W., “Investigation of microbial influence on seafloor gas-hydrate formations,” *Marine Chemistry*. Article accepted, proofed, and awaiting publication shortly.
3. Rogers, R.E., Sassen, R., Dearman, J.S., and Zhang, G., “Factors prompting seafloor experiments to investigate microbial/hydrate relationships,” presented at 16th International Offshore and Polar Engineering Conference & Exhibition, San Francisco, May 28- June 2, 2006.

EXPERIMENT TO GENERATE SHEAR WAVES IN THE SEA FLOOR AND RECORD THEM WITH A HORIZONTAL LINE ARRAY

The integration and application of the Input/Output (I/O) sensor to the Horizontal Line Array is desirable as the resolution, accuracy and low frequency response of this true digital sensor is superior to that of marine 3 axis geophone sensors. The root of the problem for use of this sensor is in the interfacing of the sensor to a non-I/O data-collection system. I/O has developed this sensor as part of a highly integrated seismic system which can collect data from 10's of thousands of these sensors every 10 to 20 seconds. This requires very fast data transmission which I/O has developed as a data interface that is both proprietary and elegant. The adaptation of portions of this data transmission scheme and repackaging or redesigning of this data collection scheme is the major part of the effort necessary to integrate the sensors into the SFO data retrieval system. In the event of any further difficulties it is possible to begin testing and interface to a 3-axis geophone and upgrading to the I/O sensor as the interface is completed. This is a duplication of effort and will require additional funding to develop a marine geophone housing capable of the depths of MC118 – 900m - and for the analog data collection system to collect the information. As a result, in an effort to stay within the present budget, we have delayed the installation of the test HLA until the I/O sensor interface can be completed.

SDI Visited Input/Output Corp. in Houston, Texas and met with both the land seismic and marine seismic equipment groups to resolve issues of support and interfacing of the Digiseis accelerometer sensor to the Sea-floor Observatory (SFO) data acquisition and recovery systems. The land seismic group had been supporting our efforts to complete the interfacing of their sensor systems. However, the retirement of one individual, departure from I/O of a supporting engineer and health issues of another key individual at I/O had left SDI without completion of the software and hardware issues. The present status of the problem was discussed and within both the land and marine groups new help has been identified and a commitment to support our efforts has been made. There have also been upgrades and enhancements to the I/O equipment that may significantly help the Horizontal array systems. We expect significant progress during the December 2006 and January 2007 time frame.

ACRONYMS

3-D	three-dimensional
4-C	four-component
13C	Carbon 13
ALA (=VLA)	acoustic line array
AUV	autonomous underwater vehicle
BCS	Barrodale Computing Services, Ltd.
BBLA	benthic boundary layer array
C&C	Chance and Chance
CH4 (=CH_4)	methane
cmbsf	centimeters below sea-floor
CMRET	Center for Marine Resources and Environmental Technology
CO2 (=CO_2)	carbon dioxide
CSA	chimney sampler array
CTD	conductivity, temperature, depth (sensors)
DATS	Data Acquisition and Telemetry System
DIC	Dissolved Inorganic Carbon
DOC	Department of Commerce
DOE	Department of Energy
DOI	Department of the Interior
DRS	Data Recovery System
EGL	Exploration Geophysics Laboratory
FY	Fiscal Year
GOM	Gulf of Mexico
GOM-HRC	Gulf of Mexico-Hydrates Research Consortium
HLA	horizontal line array
HRC	Hydrates Research Consortium
HSZ	Hydrate Stability Zone
I-O; I/O	Input-Output Corporation
JIP	Joint Industries Program
JSL	Johnson SeaLink
LUMCON	Louisiana Universities Marine Consortium
mbsf	meters below sea floor
MC	Mississippi Canyon
MD	Marion Dufresne
METS	methane sensor
mM	millimolar
µM	micromolar
MMRI	Mississippi Mineral Resources Institute
MMS	Minerals Management Service
MS/SFO	monitoring station/sea-floor observatory
NETL	National Energy Technology Laboratory
NIUST	National Institute for Undersea Science and Technology
NOAA	National Oceanographic and Atmospheric Administration
NURP	National Undersea Research Program

OBC	ocean-bottom cable
OLA (=OVA)	Oceanographic Line Array
OVA (=OLA)	Oceanographic Vertical Line Array
OTC	Offshore Technology Conference
PCA (=PFA)	pore-fluid array
PFA (=PCA)	pore-fluid array
P-SV	converted-shear mode (P-wave to SV-shear wave conversion)
P-wave	compressional wave
ROV	remotely operated vehicle
R/V	Research Vessel
SDI	Specialty Devices, Inc.
SFO	Sea Floor Observatory
SFP	Sea Floor Probe
SS/DR	shallow-source/deep-receiver
S-wave	shear wave
UNC	University of North Carolina at Chapel Hill
US	United States
USBL	ultra-short base-line (locating system)
USGS	United States Geological Survey
VLA	vertical line array
VSP	vertical seismic profile

APPENDIX:
R/V SEWARD JOHNSON/JOHNSON SEALINK CRUISE
September 11-17, 2006
Participant and Project List

PARTICIPANT	AFFILIATION	PARTICIPATION SUPPORTED BY	PROJECT
Bob Woolsey	CMRET	MMS/DOE/STRC	A, Chief Scientist
Paul Higley	SDI	DOE/STRC	A, B
Jesse Hunt	MMS	MMS	Funding Agency Representative/Support
Jeff Chanton	FSU	DOE	A
Laura Lapham	UNC	DOE	A
Kevin Martin	USM	DOE/STRC	D
Rich Camilli	WHOI	STRC	B
Norm Farr	UNC	STRC	B
Oscar Pizarro	WHOI	STRC	B
Howard Mendlovitz	UNC	STRC	B
Joanne Goudreau	WHOI	STRC	B
Chris Martens	UNC	DOE/STRC	C, H
Karen Lloyd	UNC	STRC	H
Dan Albert	UNC	STRC	H
Roger Sassen	Texas A&M	DOE/STRC/MMS	E, I
Rudy Rogers	MSU	DOE/STRC	E
Noakes	UG	STRC	F
Mandy Joye	UG	STRC	G
Ian MacDonald	Texas A&M	STRC	G
Vladimir Samarkin	UG	STRC	G

PROJECTS:
A. Pore-Fluid geochemistry/Osmosamplers/SeaFloor Probe deployment
B. Benthic Boundary Layer Array/organic geochemistry
C. Chimney Sampler Array/ Vent geochemistry
D. Bubble Counter/Acoustic Properties of Vents
E. Hydrate Formation/Collector
F. Microbe collector
G. Microbial community Analyses
H. *Beggiatoa* communities/geochemistry at vents
I. Site Characterization/Hydrate Analysis
J. BioLec biobattery

Gulf of Mexico Gas Hydrates Research Consortium
Seward Johnson Cruise, MC 118, September 11-17, 2006
Description of Observations, Deployments and Preliminary Findings

Bottom Locations: Major sea-floor observatory deployments were made in the vicinity of two crater complexes located in the southwestern and northwestern portions of the mound that occupies the south-central portion of MC118 in the northern Gulf of Mexico. Usable data were retrieved from the two probes deployed on the northern flank of the mound in May, 2005.

SOUTHWEST CRATER AREA:
Seabed bathymetry is dominated by the surface expression of a major fracture zone consisting of a series of NNE/SSW fault-controlled valleys and ridges. The central valley and ridge system is best exposed and is characterized by the occurrence of hydrate and inter-bedded authigenic carbonate slabs in the valley floor, in various stages of erosion, together with large patches of hemipelagic sediment and clam shells (see accompanying figures). A ridge approximately 100-150 yards long, 20’ to 30’ high, and 50’to 75’ wide was discovered. Zones of active venting were observed on either flank (6’ to 8’ high and 30’ to 40’ wide) that also revealed inter-bedded hydrate and authigenic carbonate in approximately equal proportions. The significant hydrate exposure on the western flank (Hydrate Wall) of the ridge (Hydrate Ridge) with associated gas vents, is the site of the bulk of the various experiments deployed in the Southwest Crater area (Figures 1 and 2). Approximately 150’ to 200’ to the NE, on the east flank of Hydrate Ridge is an erosional remnant of a slab of hydrate (50% hydrate, 50% authigenic limestone) measuring approximately 20’ long, 5’ to 6’ thick and tapering from 8’ to 4’. The structure juts out from the ridge flank over a deflation depression of fine sediment and shell. It has been named the Sleeping Dragon.

This occurrence of massive hydrates suggests a model of hydrate formation within a fracture zone, in a mud-clay lithology with the fractures acting as conduits for the upward migration of methane-rich hydrocarbon fluids. These fluids are acted upon by thriving microbial communities that produce biosurfactants which serve as a catalytic enhancement for methane hydrate precipitation. Abundant authigenic carbonate can also be attributed to bacteria-mediated precipitation.

The episodic mobilization of fracture zones from movement of the underlying salt dome has apparently continued over an extended period of time, judging by the surface exposures of hydrate and carbonate products of the transiting hydrocarbon fluids.

Instrumentation deployed in proximity to the fault zone hydrate outcrops and vent sites includes:

MICROBIAL EXPERIMENTS:

Hydrate Collector - to test relative growth of hydrates on various mound-type sediments, mediated by bacterial surfactants.
MSU/NURP

Microbial Collector - to collect microbes in the vicinity of venting methane
UGA/NURP

Biolec – to investigate feasibility of a microbial micro-electric power generator for the development of a trickle-charger for battery life extension.
Droycon Bioconcepts/MMS

CAMERAS:

Snap Camera - 360 degree, time-lapse camera for monitoring gas venting and bacterial mat growth.
UGA-TAMU/NURP

Stereo Camera - specially designed for bottom mosaic photography.
WHOI-UNC/NURP

GEOCHEMISTRY:

Peepers - collection of near-surface hydrocarbon fluids.
FSU-UNC/DOE

Mini Pore Fluid Array (PFA) - long-term collection of pore fluids from 20” sediment depth.
FSU-UNC/DOE

Mass Spectrometer; - specially designed for high resolution chemical analysis at 1000m water depth (used on multiple dives).
WHOI-UNC/NURP

Water Samples; - Collected at multiple sites via JSL provided Niskin samplers.
WHOI/NURP

HYDRATE:

Hydrate Sample - Collected via specially designed pressure vessel available from previous project
UGA-TAMU/NURP

Push Core Samples - Collected at multiple sites via JSL provided push corer
All teams/NURP

NORTHWEST CRATER/ NORTH RIM

Bubble venting typically occurring in these areas was not observed, but the WHOI Mass Spectrometer indicated a high concentration of methane and accessory gases (mainly propane) in solution in the bottom boundary layer, suggesting local seabed sources.

Both the PFA (pore fluid array) and geophysical (thermister) array deployed in

May, 2005, were located and recovered in good condition. While the osmo samplers of the PFA must be analyzed in the lab, the first two months of thermister data were retrieved and analyzed onboard. An unusual diurnal variation of 0.2^{o} C (accuracy to 0.001) was noted in the bottom water thermal profile with an approximately 3-hour delay in perturbations recorded by the thermister at 1m depth. The bottom-most thermister (4m) recorded a very stable trace. A slight diurnal tidal current effect has been apparent at the study site for an extended period of time. It may be that the tidal effect is displacing the loop current gyre ever so slightly, but sufficient to induce a noticeable cyclic temperature shift.

What appeared to be a very recent gas blow-out in fine-grained sediment of the seabed was observed at this site. The blow-out crater measured approximately 20' in diameter and 8'to10' in depth. The edge of the crater had a very sharp crest with no smoothing by the typical .2 to .4 knt bottom current. Away from the crest was the fall-out of sediment discharged from the crater and covering the microbial mats of the stable seafloor.
Perhaps the magnitude 6 earthquake approximately 50 miles to the SSW, that occurred two days previous to the observation, was sufficient to initiate the blow-out. Likewise, the earthquake may have triggered a regional discharge of gas semi-trapped beneath the surface sediments. This would explain the disruption of venting over the region and suggests that it might require some time to reestablish/recharge.

Instrumentation deployed at the northwestern site:

Osmo-Sampler - Replacement module attached to PFA;
SDI-FSU-UNC/DOE

The Lander device and associated instruments were deployed along the Northern Rim in an area where a high methane flux was detected and where bubble venting had been observed (March, 2006) using the Deep See drift camera. The Lander was recovered at the end of the dive period for final adjustments before incorporation into the observatory net work.

Lander-deployed equipment included;
CSA (Chimney Sampler Array) - for monitoring venting hydrocarbon fluids includes CTD, METS (methane) sensor, oxygen sensor, pressure sensor and camera array
UNC-WHOI/NURP
BBLA - moored 75m above the sea-floor monitors boundary layer concentrations of hydrocarbon fluids includes CTD, METS sensor, ADCP (acoustic doppler current profiler), oxygen sensor, fluorometer (on lander),
WHOI-UNC/NURP
Bubble Counter - Instrumentation to monitor bubble flux of venting hydrocarbons using electromagnetic coils, USM/NURP

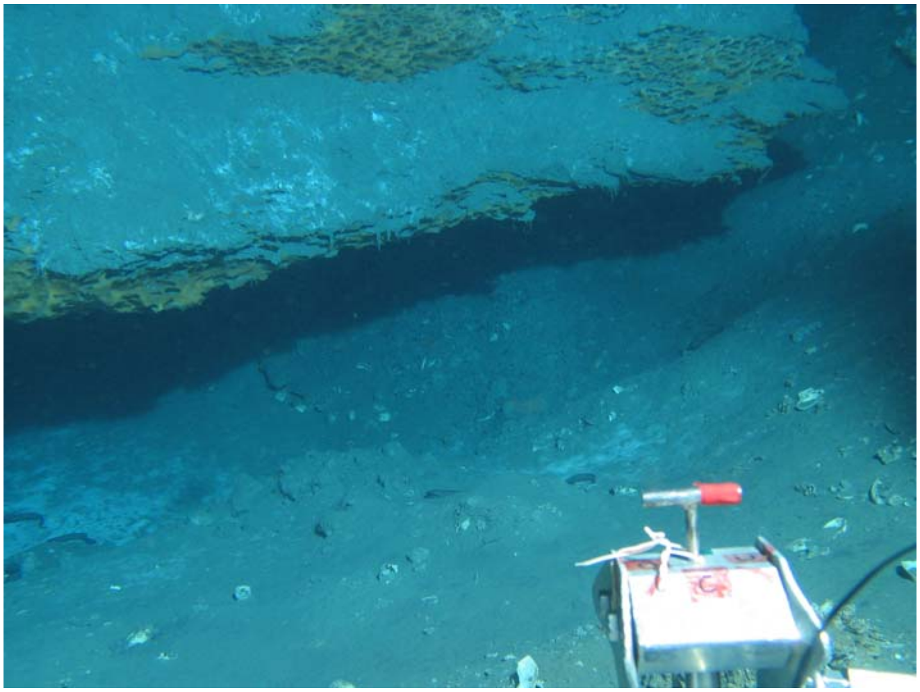


Figure 1. Wall of interbedded hydrate and carbonate (hydrate pressure chamber collector in foreground).

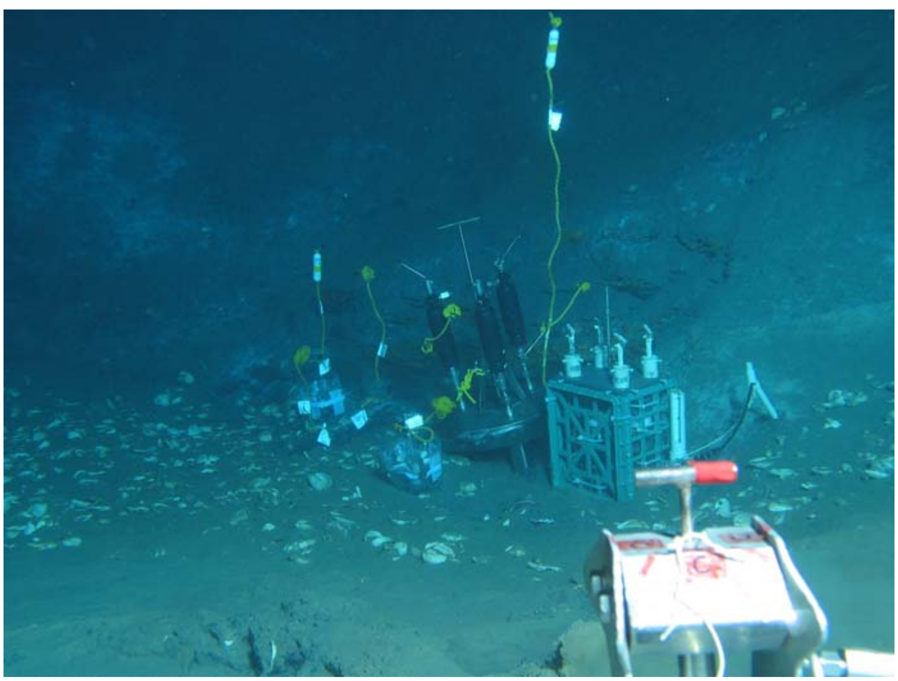


Figure 2. Observatory components deployed at the foot of the wall of hydrate: Peepers, hydrate collector, mini-osmosampler (left to right).

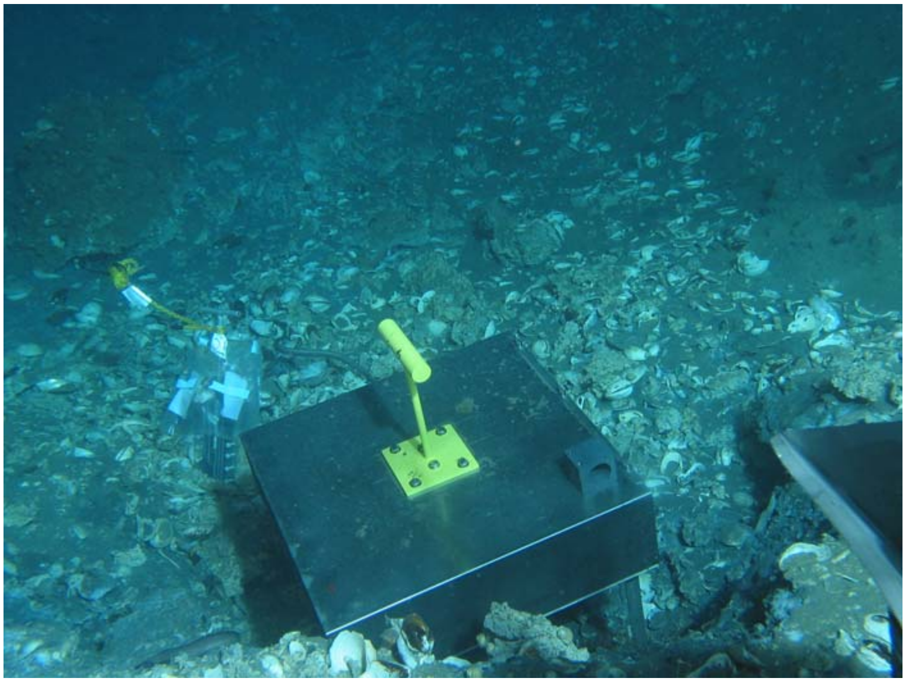


Figure 3. Microbial collector (foreground) and pore-water equilibration device (peeper) to collect *in situ* methane concentration data.

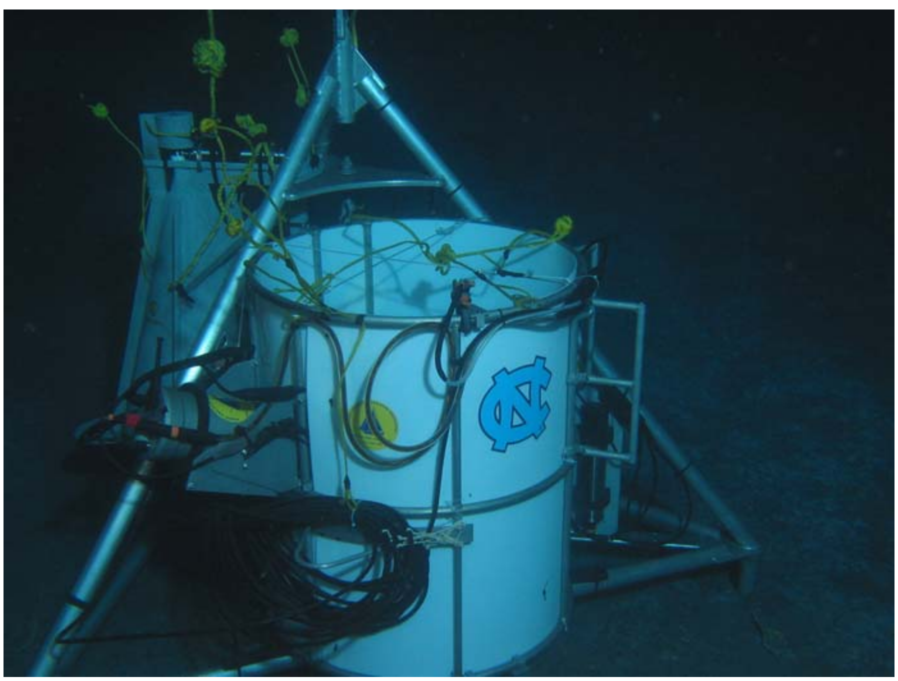


Figure 4. Lander tripod frame with CSA in foreground and bubble-counter in background. BBLA ascends from the Lander, which supports the fluorometers and power supply, into the water column.

R/V Seward Johnson/Johnson Sea Link Cruise
Mississippi Canyon 118 Observatory
September 11 – 17, 2006
Center for Marine Resources and Environmental Technology
MMS/DOE/NIUST

Dive Log
Jesse L. Hunt, Jr., MMS, Nav. Log
(times are EDT)

Tuesday, September 12, 2006:

Dive 3566
Pilot: Phil Santos
Front Obs: Paul Higley
Crew: Allen Fuller
Rear Obs: Bob Woolsey

Purpose: Land in large N. crater, take punch cores, deploy sonar target, survey north and locate Pore Fluid Analyzer (PFA) and 2nd scientific package. Attempt to recover PFA.

- 08:20 Launch 28-51.1219'N 88-29.7483'W
- 08:21 Permission to dive. Surface current indicated at 220 at 1 kt. Below surface, current from east at 0.5 kt. Sub approx. 500 ft. west of target on bottom – had to motor.
- 09:11 Bottom in sight, heading 075 500 ft. to site. Search for crater begins, question if navigation is off. Passed 4 cylindrical filter packages.
- 09:31 Stopped to take tube cores: fix 28-51.2699'N 88-29.5629'W Temp. 5.42 Depth 2915 ft Visibility 20 ft. Current 0.2 kts. Took 6 punch cores and 1 Niskin
- 09:57 Done sampling
- 10:00 Underway proceeding to sonar target due N @ 450 ft. range.
- 10:11 Site of large boulders and gorgonians, large slab of rock about 30 ft across.

- 10:18 Crater with large mound, depth 2903 ft., shell hash and bacterial mat. No seeps or hydrates.
- 10:26 Bottom of crater, depth 2915 ft., deepest point yet. Deploy sonar target. Fix 28-51.2973'N 88-29.6174'W.
- 10:31 Proceed to 1st package bearing 065, range 600 ft. Underway
- 10:36 Concrete block with rebar (old mooring) depth 2894 ft. Fix 28-51.4214'N 88-51.6272'W
- 10:41 Large hole about 600 ft. diameter with prominent walls. Center of depression fix 28-51.4421'N 88-29.5996'W.
- 10:48 At sonar target. PFA – bridle is upright, with chain hanging down in box. Fix 28-51.4682'N 88-29.4969'W, depth 2903 ft. Trying to push bridle to side to see if chain goes with it.
- 10:58 Bridle to side, will now try to pull grenade pins.
- 11:03 Pulled 2 pins on down-current side, will attempt to pull the 2 on the up-current side. Valve is on N side also.
- 11:07 Valve is closed, will now attempt to pull other 2 pins.
- 11:12 Removed the other 2 pins. Will deploy the generator at this location adjacent to bacterial mat (in already established footprint).
- 11:15 Generator deployed. Will take 2 punch cores.
- 11:20 Took 2 punch cores, tripped the other 5 Niskin bottles. Will attempt to retrieve the PFA.
- 11:25 PFA on board, permission to leave bottom

Dive 3567
Pilot: Phil Santos
Front Obs: Mandy Joye
Crew: Allen Fuller
Rear Obs: Kevin Martin

Purpose: To locate the site, place hydrates collector on the seafloor adjacent to a gas seep, take push cores and water samples, survey and photograph the area.

- 16:50 Launch. Fix 28-51.1543'N 88-29.3941'W
- 16:52 Permission to dive.
- 17:25 Depth 2400 ft., get underway heading 180, range 160 ft.

- 17:35 Bottom in sight.
- 17:37 Head 082 degrees for 60 ft.
- 17:39 On Bottom. Temp. 5.37C Depth 2906, vis. 25-30 ft. current 045 at 0.3 kt. At the top of a drop off, many gorgnians. Fix 28-51.1413’N 88-29.5180’W.
- Depth 2909 ft. Big hydrate mound. Oil bubbled out when a piece was broken off. Deploy Jeff’s peeper and radar reflector. Fix 28-51.1405’N 88-29.5275’W
- 17:54 Deployed sonar reflector #1 at hydrate mound/oil seep.
- 17:56 Pilot notes hydraulic leak on manipulator arm.
- 18:00 Pilot reports use of the arm to be limited. Will continue surveying.
- 18:12 Found good gas seep. Looks like amphitheater Depth 2916 ft. Took 6 Niskin samples, deployed hydrate sampler. Fix 28-51.1529’N 88-29.5562’W
- 18:15 Hydrate sampler on bottom but not level, next to good gas seep. Only opened one valve due to hydraulic leak. Will have to adjust and open the other valves on later dive.   Fix 28-51.1599’N 88-29.5557’W
- 18:32 Shooting video and stills around the hydrate mound
- 18:44 Reported seeing pink coral. Fix 28-51.1841’N 88-29.5576’W
- 18:55 Depth 2901 ft. Fresh hydrate site with recent eruption of gas – fresh mud expulsion.
- 19:00 Good area for hydrate sample fix 28-51.1656’N 88-29.5653’W
- 19:02 Request numbers for NW site – too far, suggest bearing of 315 degrees.
- 19:14 Heading 315 degrees – began to run out of features. Turned to heading 180 degrees.
- 19:25 Came across rock outcropping with 2 big balls of monofilament line. Fix 28-51.1126’N 88-29.5712’W
- 19:38 Circumnavigated area – back to radar reflector. Sit on bottom for fix. Fix 28-51.1361’N 88-29.5712’W
- 19:40 Permission to leave bottom.

Wednesday, September 13, 2006

AM Dive 3568
(Winds 310 to 329 degrees at 13 kts.)
Pilot: Craig Culligan
Front Obs: Rich Camillo
Crew: Frank Lombardo
Rear Obs: Oscar Pizarro

Purpose: Locate yesterday's PM position, test mass spectrometer, locate site to deploy chimney lander.

- 08:06 Launch Fix 28-51.0566 88-29.5117
- 09:14 Bottom in Sight, Looking for yesterday's site. On bottom Temp 5.4C Depth 2895 ft. Visibility 25 ft. Current 0.2kt @ 050
- 09:58 Gas seep area with numerous rocks, not good for lander
- 10:06 Tripped 2 Niskins in gas seep, running mass spec. in bubble stream. Fix 28-51.1841 88-29.5576 Sighted pink coral clump with much more beyond.
- 10:36 Over mud bottom, going back east, will scan at 750 ft. range on sonar looking for rim of feature – still can't find it. Small crater at 120 degrees about 220 ft. away
- 10:45 Back at the crater with big rock and hydrates as before, Will head 270.
- 10:50 Nothing but shell hash, no rocks – will head 045.
- 10:52 Back in pink coral again.
- 10:55 Depth 2896 ft.
- 10:58 Instruct to take push cores at hydrates, gas seep, or bacterial mats.
- 11:05 Will proceed to back side of hydrates for push cores
- 11:17 Taking push cores
- 11:19 Took 8 push cores – black mud, seeping out of flap valve, also tripped a Niskin
- 11:22 Putting float on top of a small boulder on top of the rise, depth 2902 ft., Marker #7, can see the reflector about 30 ft. down slope at 030 degrees.
- 11:25 Permission to leave bottom

Note: Submersible navigation erratic – fix jumping around badly. Never could find the hydrates collector deployed yesterday.

Wednesday, September 13, 2006

AM Dive 3569
Pilot: Don Libatore
Front Obs: Roger Sassen
Crew: Frank Lombardo
Rear Obs: Nick Brown (Discovery Channel)

Purpose: Discovery Channel PR, locate hydrate collector (Rogers device) and open other 2 lower valves and reposition, deploy methane saturation peepers adjacent to hydrate, deploy Noakes microbiological generator, collect cores and water samples.

- 16:40 Launch, Permission to dive, hover near surface for ROV filming of sub.
- 17:22 Bottom in sight
- 17:23 On bottom, Temp 5.4C Vis. 25 ft. Depth 2900ft. Currents 0.2kts at 030 degrees. Flat mud with scattered shells, structure visible on sonar, will proceed NE (045 degrees, range 250 ft. Fix 28-51.1371N 88-29.5987'W
- 17:25 Underway
- 17:26 Gorgonians or possibly corals coming up. Large flat rock with pink coral, lots of crabs. Depression, will look around.
- 17:34 Follow sonar into depression, depth 2913ft., coming back up.
- 17:35 Half piece of PVC about 5 ft. long, will head 140 degrees 455 ft.
- 17:40 Back up slope. Back to 2900 ft., pieces of rock – looking around.
- 17:42 Cdhange course to 180 degrees. Checking out rock structure. Could be hydrates, also see battery tracks, will look around.
- 17:44 Shallow depression with debris.
- 17:45 Active gas vent, depth 2899 ft.
- 17:46 Depth 2900 ft., like something in Mandy's video
- 17:47 Will try to get Niskin sample over the gas seep and close.
- 17:52 Tripped Niskin #5 & #6 in bubble stream. Fix 28-51.1679'N 88-29.5561'W By nav., only 40 ft. from sampler

- 17:55 Will deploy hydrate growing core barrel for Roger to film
- 18:12 Over the same vent picking up rock
- 18:20 Dropping marker float #6 10 ft. away from vent, moving 100 degrees.
- 18:22 Marker 2 ft. off bottom. Depth 2900 ft.
- 18:25 Will jump over adjacent ridge and see what is there.
- 18:26 Descending into crater on other side of ridge.
- 18:30 Very pock marked and eroded in crater. Large hydrate mass looks almost like a bridge.
- 18:31 Depth 2906 ft. Heavily eroded bottom, very large hydrate chunks.
- 18:35 20 ft. long by 4 ft. high chunk of hydrates protruding from the bottom. No gas vents. Moving toward reflector 240 degrees.
- 18:36 Reflector in sight
- 18:38 Depth 2906 ft.
- 18:41 Moving 310 degrees toward hydrate sampler, expect it to be 200 ft. away.
- 18:55 Back where started from. Will deploy Noakes microbio. Experiment there. Marker 6. Depth 2900 ft., just upslope from seep. Fix 28-51.1895N 88-29.5317'W Will install Noakes device in small depression along with peeper.
- 19:15 Noakes instrument deployed at 5 degree angle, now deploying peeper.
- 19:20 Got peeper in to proper depth, will move a couple of feet and attempt to take push cores
- 19:24 soft sediment off to side, will push cores.
- 19:30 Placing cores in quiver, water coming out of top disturbing cores.
- 19:35 Cores should be 3 and 3 (located together) about 20 ft. or less apart between groups. Found a flat spot about 50 ft. across which might be good for chimney lander.
- 19:46 Only 5 punch cores, one lost. Fix 28-51.1752 88-29.5728 Will run 240 degrees for short while to look for sampler
- 19:52 Sub at 2910 ft. will keep going briefly.
- 19:54 Time to go. Permission to leave bottom   Depth 2919 ft.

Thursday, September 14, 2006

AM Dive 3569
Pilot: Don Libatore
Front Obs: Rich Camillo
Crew: Allen Fuller
Rear Obs: Oscar Pizarro

Purpose: Find a suitable site for the chimney lander, and search for the Pore Fluid Analyzer. Re-install the osmopump on the PFA probe.

- 08:24 Launch and permission to dive.
- 08;29 Getting underway at 090 degrees, depth 100 ft.
- 09:08 On bottom. Temp. 5.81C Vis. 25-30 ft. Depth 2877 Current 0.1 kt at 040 degrees Fix 28-51.5033'N 88-29.7290'W proceed on heading of 100
- 09:13 Filming squid getting underway @ 100 degrees
- 09:15 Collected squid in suction
- 09:21 Shell hash, looks like edge of small depression
- 09:26 Came across vent tubes – will collect
- 09:33 Shell hash, bacterial mats, and vent tubes
- 09:34 Following bacterial mat to see if it leads to vent
- 09:35 Will set down on bottom and take punch cores depth 2890 ft. 2 punch cores in center of mat, 2 on the edge, and 2 in mud away from the mat
- 09:45 In center of mat, only able to penetrate half way and hit hard layer
- 09:47 Found area of vent tube chimneys, 7 to 8" long, 1" diameter fix 28-51.4865'N 88-29.6932'W
- 09:55 Retrieved several vent tube chimneys, they extend several inches into the seafloor
- 10:01 On site that might be good for lander – flat, has bacterial mat, and gas seeped out of holes after cores taken. **Mass spectrometer almost off scale for methane**
- 10:10 All push cores on board, will take Niskin samples over and off of mats. Mass spec. seeing high levels of methane, butane and propane. Niskin #1 & #3 taken outside the mat, #2 hung up. Fix 28-51.4872'N 88-29.6224'W

- 10:15 Took Niskin #4 &#5 over bacterial mat. Will follow the edge of the feature to the east. 20 degree slope @ bottom, depth 2890 ft. **Fix 28-51.4907'N 88-29.6421'W - Site for lander**
- 10:29 Going to position mass spec. over one of the vent chimneys
- 10:35 Going back to center of bacterial mat and deploy Marker #8
- 10:38 Deployed marker near the top of the rim depth 2883 ft. at the weight]
- 10:57 Found GFA (Geophysical array deployed last year) Took video for later planning and retrieval
- 11:19 Found the PFA(pore fluid array) probe
- 11:40 Installed the osmopump on the PFA
- 11:41 Shot video, permission to leave bottom. Depth 2890 ft. Fix 28-51.4553'N 88-29.5258'W

September 14, 2006

Between dives, 13:00 to 17:00, deployed the chimney lander with floats to acoustic release. Attempt to position it on bacterial mat observed on morning dive. Afternoon dive will attempt to fine tune position over the mat. Plan to retrieve lander on Saturday with acoustic release from weight and retrieve at surface.

PM Dive 3570

Pilot:	Don Libatore
Co-pilot:	Phil Santos
Crew:	Allen Fuller
Rear Obs:	Norm Farr

Purpose: Relocate chimney lander, detach camera system on tether from it and place in close proximity, reposition the lander over the bacterial mat sampled this morning. Attempt to relocate geophysical array probe and retrieve data logger, collect water samples.

- 17:25 Launch, Permission to dive
- 18:12 75 ft. off bottom, floats are strong on the sonar about 300 ft. out

- 18:18 Lander appears to be in the basin. Sub currently at the marker left this morning (Marker 8). Heading to lander 085 degress 100 ft.
- 18:21 Can see lander. Appears to be sitting on bottom fairly level and everything appears intact.
- 18:22 Appears to have slid 15 to 20 ft. down slope, sitting at angle of about 25 degrees. Look around first; will take bubble camera off and put it upslope so won't have to deal with wire.
- 18:24 Taking still photos of the lander and will then deal with it.
- 18:32 Camera is off, will find a vent chimney on the side away where cable will be stretched out to put it.
- 18:36 Placing the camera over a vent tube about 50 ft. from the lander at a heading of 060 degrees. Toppled over, picked it back up and put the heavy side upslope. Now sitting upright and stable Fix 28-51.5107'N 88-29.6237 W
- 18:40 Repositioned cans upslope.
- 18:47 Lander relocated over the bacterial mat about 10 ft. from where cores were taken on morning dive. Bottom report: Depth 2889 ft. Temp. 5.49C Visibility 25-30 ft. Current 0.1 kt from 050 degrees
- 19:02 Taking Niskin #1, #2 and #3 are the same that didn't trigger this morning. Fix 28-51.4996'N 88-29.6485'W
- 19:05 Got Niskins, heading back to lander to check everything and then proceed to GPA.
- 19:07 At the CTD, 60 ft. off bottom, depth 2829 ft.
- 19:10 Off to GPA, heading 110 degrees range 660 ft.
- 19:14 Took video of acoustic release, underway at 110 degrees
- 19:17 Sonar hit 150 ft. out at bearing of 134 degrees
- 19:22 Have GPA in sight
- 19:24 Looks like it is stuck in the mud, can only see 2.5 squares of concrete, the rest is buried.
- 19:30 Discussion of how it is mounted, bumped it with sub, appears stable, will try to pull the can
- 19:32 Cut twist ties and string, pulled on handle and it broke off.
- 19:37 Suggest trying to push it apart.
- 19:40 Got connectors disconnected and will try to pull it apart.

- 19:45 Successfully got it apart and have the data logger bottle on board. Depth 2900 ft., Permission to leave bottom. Fix 28-51.4398'N 88-29.5517'W

Friday, September 15, 2006

AM Dive 3572
Pilot: Phil Santos
Front Obs: Ian McDonald
Crew: Frank Lombardo
Rear Obs: Karen Lloyd

Purpose: Locate Rudy's hydrates generator, level it, and open the other 2 valves; Deploy Ian McDonald's time lapse camera, Deploy hydrates peepers, deploy osmolander, take push cores and water samples.

- 08:11 Launch, Permission to dive
- 08:54 On bottom, depth 2906 ft., Temp 5.54C Vis. 30 ft., current 0.2 kts from 070 degrees Fix 28-51.1327'N 88-29.5877'W
- 08:55 Picking up good sonar target
- 08:57 Proceeding to target at 180 degrees range 100 ft.
- 09:00 At pink coral – good targets 140 ft. out, will check. Depth 2980 ft. 10 ft. off bottom.
- 09:01 At Noakes experiment – will continue 100 ft. toward other target
- 09:02 Pink coral to Noake's experiment, course 180 degrees. At marker #6 at top of the hill by Noakes experiment. Bridge about 100 ft. from #6, but can't remember the direction.
- 09:10 Depth 2903 ft. At a hydrate hole leaking oil Fix 28-51.1582'N 88-29.4920'W
- 09:15 Target about 100 ft. bearing 125 degrees
- 09:20 Rudy's experiment in sight, due S from #6. Rudy's experiment is about 40' S of marker 6, just over the ridge
- 09:25 Setting down to do work. **Increased gas leakage from Tuesday's dive.**

- 09:31 Will take Ian's camera off sub at Rudy's experiment, will place the other marker, open valves, then come back and work.
- 09:37 Depth 2916 ft. Ian's camera is off sub, will deploy hydrates peeper Fix 28-51.1468'N 88-29.5296'W adjacent to gas stream
- 09:45 Continuing to deploy experiments
- 09:50 Rubber band on osmolander too strong, when tried to release monkey fist float, toppled lander over. Will reposition and try to free float.
- 09:52 Redeployed, will now try to remove handle and insert in bottom. Hearing pinger in sub.
- 09:56 Laura's osmolander deployed
- 10:10 Deployed 2 peepers almost 1 m. from slope, the other to be put into soft sediment 1m from hydrates
- 10:14 All peepers deployed. Back to Rudy's experiment and trip Niskin bottles.
- 10:26 Completed cores at the bacterial mat
- 10:55 Took 6 cores, back to camera to put it in place and ready to surface
- 11:05 Got camera deployed, going upslope to deploy marker (110 degrees)
- 11:14 Marker is about 50 ft. south of Rudy's experiment, everything is in roughly a N-S line
- 11:15 At sonar reflector, Depth 2906 ft. Fix 28-51.1182'N 88-29.5349'W about 50 to 75 ft. from experiment at 030 degrees
- 11:17 Permission to leave bottom

Summary of Markers Deployed

1. "Mandyville" Sonar reflector, one peeper Dive 67 fix 2851.1405'N 88- 9.5275'W
9."Rudyville" Rudy's device, 3 peepers, osmolander, bubble stream, Ian'"s time lapse camera, depth 2916' (40 ft. S of marker) 28-51.1468'N 88-29.5296'W (dive 72)   28-51.1529'N 88-29.5562'W (dive 67)
6. "Noakesville" Noakes-a-matic, one peeper 28-51.1679'N 88-29.5561'W
7. Near No. 1.
8. "Mattville" At North site where CSA deployed

Friday, September 15, 2006

PM Dive 3573

Pilot: Phil Santos
Front Obs: Bob Woolsey
Crew: Frank Lombardo
Rear Obs: John Noakes

Purpose: Bob to reconnoiter the area to familiarize himself with it for Nov. ROV work. Will attempt to take hydrates samples with pressure container, deploy hydrates peepers, take push cores and water samples.

- 16:52 Launch and permission to dive
- 17:30 On bottom, Depth 2890 ft., Temp. 5.52C, Vis. 35 ft., Current 0.2 kts. From 070 degrees Fix 28-51.1291'N 88-29.5710'W
- 17:54 Collected a large piece of gas hydrate – too large to fit down in container, put top on device.
- 18:03 Closed hydrate bomb – lid is ~ ½ inch off body of the vessel.
- 18:08 Took 2 push cores at sonar reflector site.
- 18:11 Tripped 2 Niskin bottles
- 18:16 Back near Rudy's experiment – will turn handles on milk crate osmolander so all are parallel
- 18:19 Moving peepers
- 18:25 Set the peeper brought down near hydrates
- 18:26 Had to rearrange peepers
- 18:32 Taking tub core and relocating to John's experiment
- 18:41 Coming up on Marker 6
- 18:43 At John's experiment
- 18:51 Took Niskin sample. Band came off core tube, need directions to hydrate bridge – directions: near big rock at 030 degrees about 200 ft.
- 18:55 On heading, picked up several rocks
- 18:59 Flat sand – heading to sonar target
- 19:08 At what looks like the bridge – big chunk of white ice 4-5 ft. in diameter. Headed SE to get here. Fix 28-51.1422'N 88-

29.5014'W Took last 2 Niskins, tried to take last punch core but handle came off.

- 19:15 Heading to the marker. Will try to close the hydrate bomb. Lid is stuck – can't close or open
- 19:32 Got the chunk of ice broken up, got the lid on and locked. Will place marker on the ridge – large slab of hydrate now has gas coming out of it.
- 19:33 Permission to leave bottom. Depth 2894 Fix 29-51.1593'N 88-29.5171'W (at Marker #10)

Saturday, September 16, 2006

AM Dive 3574
Pilot: Craig Caddigan
Front Obs: Howard Mendelovitz
Crew: Allen Fuller
Rear Obs: Norm Farr

Purpose: Put a grid in the lander and photograph with stereo camera and video, proceed to PFA and galvanic generator, check generator to time LED flashes, then to Site 5 at South Crater and obtain water samples.

- 08:05 Launch, Permission to dive
- 08:44 Good sonar contact, probably lander, proceeding
- 08:45 Bottom in sight
- 08:50 On bottom, Depth 2892 ft. Temp. 5.59C Vis. 20-25 ft. Current 0.2 kts. From 029 degrees Fix 28-51.4860'N 88-29.6340'W Sitting in front of lander, will video and shoot stereo photos
- 09:11 Finished shooting grid in lander, will now do stereo shots, tripped a Niskin
- 09:16 Doing stereo photos, flying off bottom back and forth.
- 09:40 Done with photos, will move back to Lander and get punch cores and Niskins
- 09:42 Depth 2895 ft. Will take 2 cores and 2 outside and trip Niskins 2 & 3

- 09:52 Got 3 punch cores, 2 inside and 1 outside, handle pulled off other core tube coming out of quiver. Got niskins; going over to Kevin's snow cone and take stereo shots and recover
- 10:03 Equipment on the sub, now to generator – 095 degrees 600 ft
- 10:05 Getting underway at 095 degrees to PFA site
- 10:12 250 ft. at 100 degrees to target
- 10:15 50 ft. at 050 degrees
- 10:16 Nothing on sonar – try 140 degrees
- 10:18 Very close
- 10:20 At site – video and film unit just E of PFA (generator), Bob wants to look straight down and see if LED's are flashing
- 10:29 When done with video, head to site 5
- 10:30 LED's flashing, time between flashes 3 sec
- 10:34 Head 245 degrees for 600 ft. to site 5
- 10:42 Just came over rocks, big crater ahead. Pop a Niskin in the crater – 10 minutes remaining on bottom
- 10:50 Kevin's snow cone fell off, waiting for mud to clear to retrieve
- 10:52 All done, Permission to leave bottom Fix 28-51.3755 88-29.5935

Saturday, September 16, 2006

PM Dive 3575
Pilot: Craig Caddigan
Front Obs: Rich Camilli
Crew: Allen Fuller
Rear Obs: Oscar Pizarro

Purpose: Run the mass spectrometer over the features, obtain stereo photography over the features, take push cores and water samples and deploy another galvanic generator.

- 15:44 Launch and permission to dive
- 15:51 Asked that lander not be shut down – too late, already ran shut down program – possibility of data corruption.
- 16:19 Bottom in sight- range and bearing 090 degrees 200 ft.

- 16:20 John's experiment in sight. Set down. Bottom report – depth 2905 ft. Temp 5.6C Vis. 25-30 ft. Current 0.2 from 060 degrees Fix 28-51.1657'N 88-29.5484'W Bubbles are coming up behind John's experiment, On shell hash, will deploy other generator and take photos. Will attempt push cores in softer sediment up ridge.
- 16:32 Took photos of instruments, deployed generator by Noakes experiment, will go up slope and get punch cores.
- 16:35 Depth 2896 Up on the rise, taking punch cores Fix 28.51.1807'N 88.29.5587
- 16:43 Got all 4 punch cores, one only half full – lot of oil bubbling out of holes where the cores were taken. Going back over to John's experiment, fly a little higher to get stereo photos
- 16:56 Took 2 niskins in bubble stream. Rich shut down the mass spec. – problems
- 16:59 Need range and bearings to Rudyville: 170 degrees, 40ft.
- 17:02 Went 040 degrees but don't see anything
- 17:04 Another range and bearing – 250 ft. at 350 degrees
- 17:07 Still 350 degrees 100 ft.
- 17:11 Passing a little west, come to 040 degrees
- 17:13 Depth 2908 ft. Don't see anything
- 17:15 Head 170 degrees for 130 ft. (to #1 radar reflector)
- 17:18 At pink coral and rubble – close to John's site, come to 150 degrees
- 17:23 Passed over 2 big spools of monofilament line – head 030 degrees for 150 ft.
- Sitting on the pink coral again. Head 080 degrees to John's experiment, need range and bearing to hydrate ridge
- 17:30 At John's experiment
- 17:31 At Marker 6 – go over the bank and should be near Rudy's experiment. Went to ice bridge, reflector and took photos, then to Rudy's
- 17:45 Around area taking stereo photos, still photos and video
- 18:42 Permission given to leave bottom when done
- 18:46 Tripped niskin 6, have 5 niskins and 2 more punch cores, depth 2896 ft. Fix 28-51.1600 88-29.5444 Leaving bottom

18:10 Had pod of pilot whales and spinner dolphins N of the vessel.